

Conference Paper

Use of the Waste Foundry Sand in the Composition of Hot Sandy Dense Asphalt Concrete

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Abstract

There is an increase in motorization worldwide, which in turn requires the construction of high-quality roads and highways. In both new construction and reconstruction of the pavement, large volumes of natural mineral materials are used, placing a large technogenic load on environmental objects during their extraction. In a number of regions of the Russian Federation, there are not sufficient volumes of conditioned raw materials for the production of high-quality composite building materials, such as asphalt concrete and cement concrete mixtures. The use of industrial waste in the composition of building materials addresses this issue while both solving environmental issues and reducing the cost of road construction. This article shows that developed countries successfully use the resource potential of waste in the production of building materials. This article proposes the use of waste foundry sand as the mineral raw material in the production of asphalt concrete. The article presents research on the following: geometric shape, elemental composition of the surface of the particles of the waste foundry sand; bitumen capacity; and the adhesion of bitumen. Based on the obtained data, a technology was developed for producing hot sandy asphalt concrete in which the waste foundry sand is used as a fine mineral aggregate. Physico-mechanical properties of the obtained samples of asphalt concrete satisfy the requirements established in GOST for asphalt concrete.

Keywords: waste foundry sand, asphalt concrete, industrial material, elemental composition, bitumen.

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At present, enterprises of the Russian Federation generate large volumes of technogenic waste, which raises the issue of their disposal. In developed countries, special attention is paid to this issue. The use of the resource potential of industrial wastes makes it possible to reduce the technogenic load on environmental objects by reducing the volumes of their accumulation and the volumes of extraction of natural raw materials, and also allows reducing the cost of the final product by reducing the cost of raw materials. One of the main consumers of industrial waste can be the construction industry, which is a large-capacity consumer of mineral raw materials of various compositions.

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One of the unexplored and underestimated industrial wastes in Russia is the waste foundry sand (WFS) formed during the production of steel olives. The basis of WFS is quartz sand, with a content of silicon oxide (SiO_2) from 95 to 97%, which characterizes this material by origin as an acidic rock.

An analysis of the scientific literature showed that WFS finds use in obtaining various target products. China, being a leader in the processing and manufacture of metal products, due to the shortage of areas for placement of waste foundry sand and other anthropogenic materials, is actively expanding the range of building composite materials by including technogenic raw materials in their composition [1].

In India, in a number of areas there is a shortage of conditioned stone mineral materials, which creates difficulties in the construction of industrial and civil buildings. To reduce it, technologies are used to replace natural fine mineral aggregate in the composition of concrete mixtures on WFS, which significantly reduces the consumption of natural mineral raw materials and the cost of the final product. The developed concrete mixes, which included WFS, showed good results in strength and waterproof characteristics with an WFS content of up to 30%. [2, 3].

In Brazil, in the face of the threat of environmental imbalance and the lack of building materials that meet the requirements of national standards, concrete compositions have been proposed that meet the requirement for a compressive strength of at least 25 MPa. In one of the developments of Brazilian scientists, the gravel-mastic asphalt concrete and blocks for paving were selected using the waste foundry sand as a fine mineral aggregate [4, 5].

In Mexico and Italy, waste foundry sand is widely used in cement concrete [6, 7]. In the United States, from 10 to 16 million tons of waste foundry sand is formed annually, of which 15-28% of the total volume is reused, and part is used to produce Portland cement, in addition, WFS is used in the construction of structural layers of pavement [8].

Previous studies of the physical and mechanical characteristics of WFS showed that WFS can be used as a fine mineral aggregate in the composition of asphalt mixtures. To achieve maximum values established by GOST indicators, a full-factor experiment was conducted to establish the technological parameters for the production of asphalt mix.

All mineral materials used in the design of the grain composition of asphalt concrete are divided into several types according to the content of silica (SiO_2): ultrabasic $\text{SiO}_2 < 40\%$; basic SiO_2 from 40 to 52%; average SiO_2 from 52 to 65%; acidic $\text{SiO}_2 > 65\%$. According to scientists who were at the origins of the study and creation of composite organomineral materials, the best adhesion of bitumen to stone materials takes place

for the main carbonate rocks. The chemical and particle size distribution of WFS are presented in [9, 10]. However, the previously obtained data do not fully disclose the resource potential of the WFS, so it is necessary to carry out a number of tests to scientifically substantiate and expand the range of building and road building materials. To confirm the practical use of technogenic material in the composition of asphalt concrete, it is necessary to perform the following comparative tests: 1 - determination of the geometric shape, elemental composition; 2 - determination of bitumen; 3 - determination of adhesion of bitumen to stone materials; 4 - test of asphalt concrete samples using WFS as a fine mineral aggregate.

1. In a number of works, the influence of the geometric shape and chemical composition of mineral materials to create a strong bitumen film on the surface of the particles, which in turn is an important link in the structure formation of a strong, absorbing all the calculated loads of the skeleton of the mineral skeleton, is considered [11–13]. The considered form and elemental composition of the WFS particles are presented in Figure 1. The elemental composition of the surface of quartz sand consists of the following chemical elements, %: 49.1 O; 0.6 Na; 49.4 Si; 0.9 others. It is worth noting that during technological processes (interaction with formaldehyde, hardener and high temperatures), the surface of quartz sand undergoes a modification, and the elemental composition of the WFS surface of the organic phase changes and consists of the following chemical elements, %: 53.5 C; 28.6 O; 2.3 Na; 3.4 Si; 12.3 other chemical elements.

It was found that quartz sand particles are characterized by a glassy well-rounded spherical shape, when in turn the WFS particles have a developed, rough shape, with a large number of defects formed by mechanical action on the material, close in shape to cuboid.

2. In order to confirm the opinion about the increase in the specific surface, comparative tests of quartz sand and WFS by the method of determining bitumen capacity in accordance with GOST 52129-2003 were made. The essence of the method is to determine the amount of oil mixed with fine mineral material to obtain the desired consistency. The bitumen capacity index characterizes the ability of a mineral material to adsorb part of a binder on itself. The bitumen capacity of WFS is 50%, and that of quartz sand is 38.1%. It is established that the bitumen intensity of WFS is higher than that of quartz sand. This gives the right to assert that when interacting with bitumen, WFS particles have better adhesion compared to quartz sand.

3. To prove the best adhesion of bitumen with WFS particles, comparative tests were carried out for compliance with GOST 11508-74. The essence of the method is to determine the ability of viscous bitumen to retain on the surface of sand previously

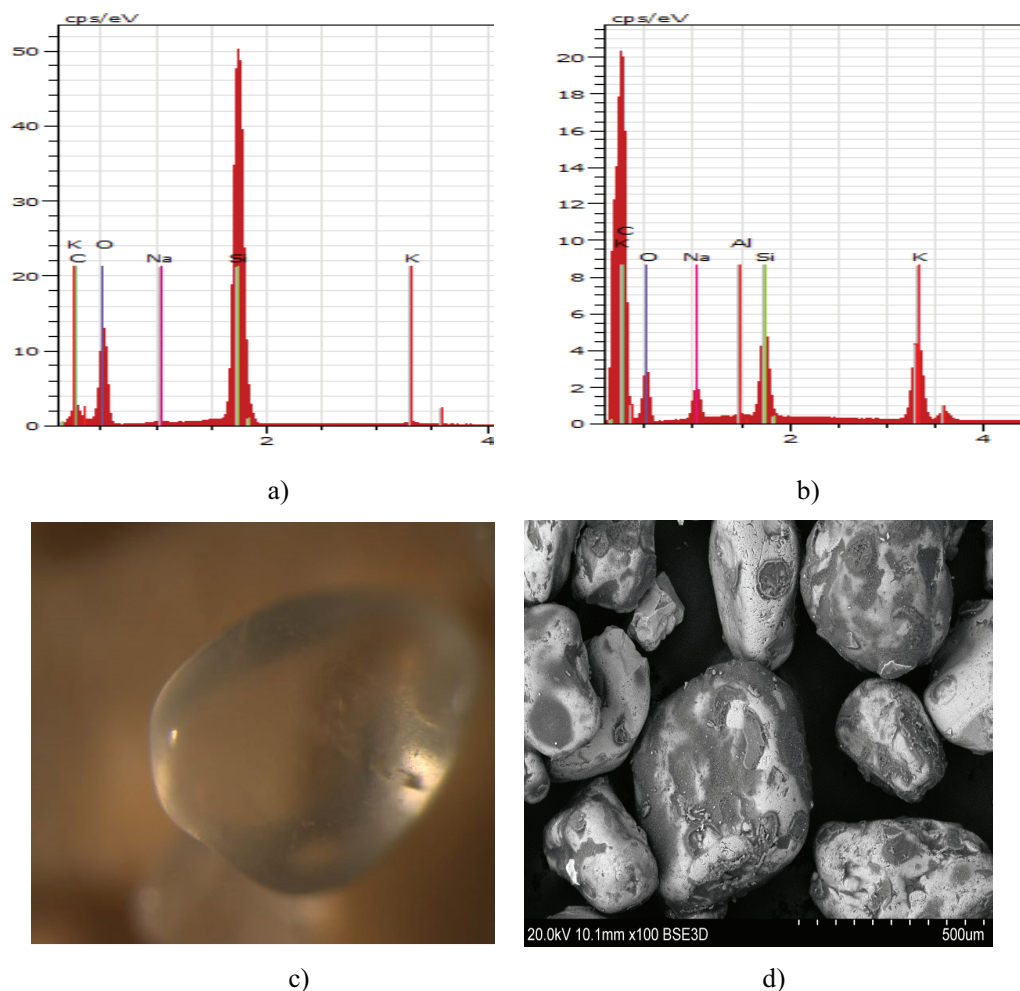


Figure 1: The surface of the particles (c, d) of quartz sand and the elemental composition (a, b) before (a, c) and after use (b, d) in the mold.

coated with it when exposed to water. It was revealed (Figure. 2) that WFS particles have better adhesion characteristics compared to quartz sand. This is primarily due to the fact that after surface modification, the acidity of the WFS material decreased, creating a strong water-insoluble bitumen film on the surface of the particles.

4. The selection of the grain composition of hot sandy dense asphalt concrete of type G grade II was carried out, where WFS was used as a fine mineral aggregate. Grain composition of the mixture: sand from the screening crushing crushed stone quarry "White Stone" - 75%, WFS - 20%, mineral powder - 5%, bitumen BND 90/130 in excess of 100% of the mineral part - 6.0%. Physico-mechanical characteristics are presented in table 1. Such characteristics as the compressive strength at 20 °C, 50 °C, 0 °C correspond to the requirements of GOST 9128-2013 and are 3.87 MPa, 1.89 MPa, 6.38 MPa, respectively.

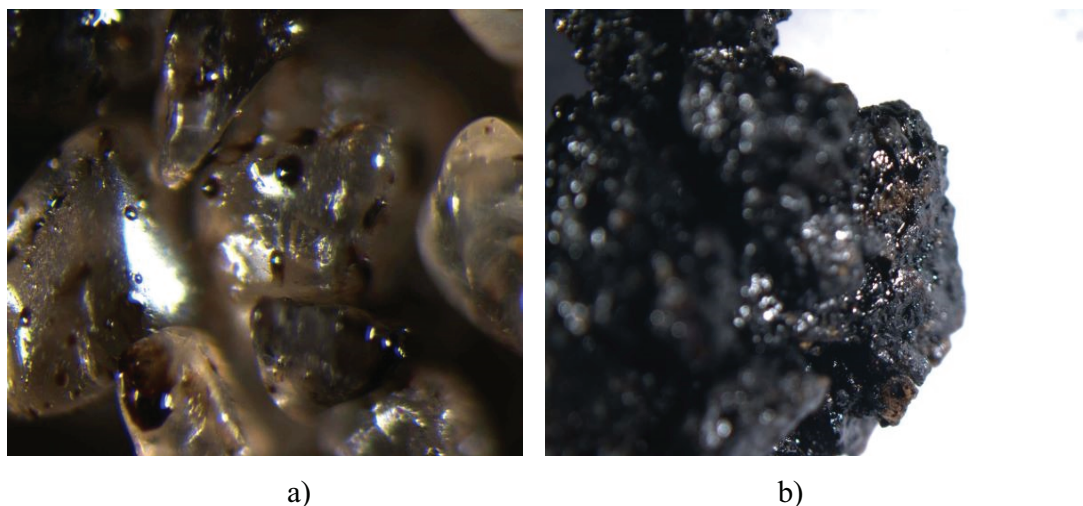


Figure 2: The results of a comparative test on the adhesion of bitumen with stone material: quartz sand after boiling (a), WFS after boiling (b).

TABLE 1: Physico-mechanical properties of sandy dense asphalt concrete type G grade II

Indicators	Requirements GOST 9128-2013	Type G brand II
Average density	-	2,40
The porosity of the mineral part	No more than 22	17,82
Residual porosity	2,5-5,0	4,00
Water resistance, not less	0,90	1,00

Physico-mechanical characteristics of asphalt concrete meet the requirements of GOST, this confirms the possibility of using WFS in the composition of asphalt mix type G grade II.

The proposed technology for the use of the resource potential of the WFS allows you to abandon the use of natural sand in the composition of asphalt concrete, reduce the amount of waste disposed of in the environment, and expand the raw material base for asphalt concrete production.

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